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Drainage and Improvement of Wet Land

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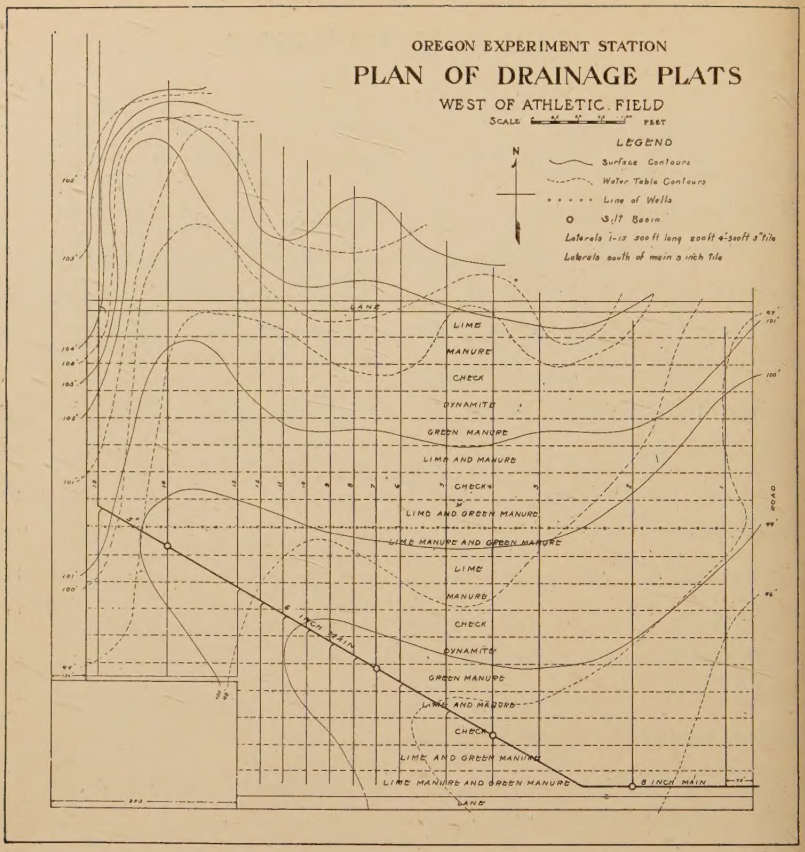

Figure 1. Plan of drainage plots, Oregon Agricultural Experiment Station.

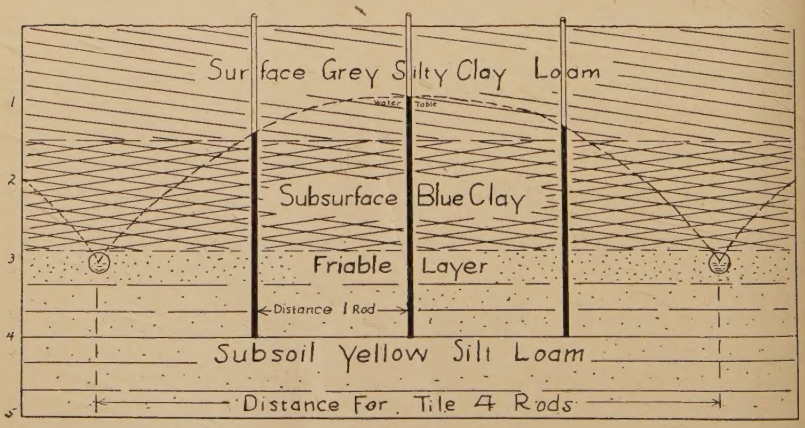

Figure 2. Condition and placement of tile.

Drainage and Improvement of Wet Land

By

W. L. Powers

Drainage is the first step in the improvement of one and one-fourth million acres, or almost one-third of the Willamette Valley floor land. There is scarcely a quarter section in the Valley floor that would not be benefited by some tile lines. Nearly a million acres of wet Willamette Valley land need tiling. One-fourth million acres require outlet ditches. Four out of five farms can be tiled without district outlets. Less than 200,000 acres of the Valley are "white land" and 280,000 acres are "half white land."

The Oregon Agricultural Experiment Station has worked out and published methods of tiling these heavy wet lands. As a result 325 miles of tile lines for farmers have been designed, mainly as extension work. These are largely installed and serve approximately 20,000 acres. According to the owners, the increase in crop value from this drainage is from $10 to $25 an acre a year. On this basis the loss in crop value from a million acres of wet occupied farm land in Western Oregon is approximately $10,000,000 annually.

Benefits from drainage. The primary object of drainage is to remove excess water. This results in improvement in soil structure, increased root pasturage, and an increased supply of capillary or usable moisture. Drainage affords better air circulation, makes soil warmer, aids decay and nitrification, lengthens the growing season, firms the soil, prevents erosion, diminishes the effect of drought, and prevents heaving and freezing out and the accumulation of acids or alkali. In addition, drainage improves sanitary conditions, promotes healthfulness, and is an aid to transportation and to the general development of the country. Timely drainage pays with big interest on money invested in increased yields and land values.

To study drainage requirements an experimental tile drainage system was installed at Oregon Agricultural Experiment Station in 1914 on a white-land field west of the stadium. The system was planned after a study of older existing tile systems on the College farm and throughout the Valley.

The tiling is arranged at different distances apart, and studies have been made of the outflow, water-table conditions, and crop yields as affected by drainage.

The value of lime, manure, rotation, and fertilizers for improvement of the land along with drainage is under observation. The treatments are shown in Figure 1.

Properties of white land. Physical analyses of representative samples of white land (Dayton silty clay loam) from the drainage experiment field show that the surface soil contains about 20 percent clay and over 55

percent silt. In other words, it is a gray silty clay loam. The subsurface is blue clay, containing more than 33 percent clay; the subsoil is yellow silt loam, containing only 17 percent clay. Just below the blue clay, or at a depth of from 3 to 3½ feet, is a friable streak, more porous than the subsoil at greater depth. It is in this friable layer just below the blue clay that it is usually best to place laterals or collecting drains. This condition and the placement of tile are shown by the accompanying sketch, Figure 2.

TABLE I. PHYSICAL COMPOSITION OF WHITE LAND FROM DRAINAGE PLOTS

Soil sample	Total sand	Silt	Clay
	%	%	%
Surface gray silty clay loam	15.66	63.73	19.86
Subsurface blue clay	23.46	44.39	33.64
Subsoil yellow silt loam	22.66	58.79	17.45

How deep should tile be? The tile should be located in the friable streak below the blue clay and should go over, under, or around thick impervious layers. In typical white land the impervious blue clay extends to about three feet from the surface and the friable streak underneath it will be at about this depth. Some white land has a thicker layer of the impervious clay. Numerous deep borings with a post-hole auger or soil auger will show how impervious the soil is, and at what depth and distance apart the laterals should be placed.

Tile draw two rods. In typical white land tile lines will need to be about 4 rods apart to provide good drainage for field crops and should be located with the aid of a soil auger so that a tile 3 to 3½ feet deep will encounter the water-bearing stratum and collect the water before it has done injury to the root zone on the heavy flat land below.

Experiments show that twenty-four hours after a heavy storm the water-table is lowered to a distance of 2 rods on each side of a tile line. In "half-white land" (Amity silty clay loam) the tile drains may be placed 3½ feet deep and 5 rods apart. This is the gray brown soil that is intermediate between the naturally drained brown soil in the Valley and the flat gray land. Advantage should be taken of high spots to omit a lateral here or there, and to use intercepting drains across the base of higher slopes to protect low, flat lands from excess water. A random or natural system of drains can be used where there is a good proportion of brown, naturally drained soil. The extent of tiling needed for "brown sticky" (Wapato silty clay loam) needs investigation.

Size and grade. The size of tile depends upon the grade. The greater the fall the smaller the tile needed. In most white land a fall of .2 foot per hundred feet can be secured for lateral drains, and .1 to .2 foot per hundred feet for main drains. This is the minimum grade desirable. The more fall the better, up to several feet per hundred. In a fall of .2 foot in a hundred a 5-inch tile will remove a half inch of rainfall per acre and serve as an outlet for about 12 acres; a six-inch tile about 20 acres; an eight-inch, 35 acres; ten-inch, 65 acres; and a twelve-inch tile, 100 acres.

TABLE II. DISCHARGE FROM LATERALS PLACED DIFFERENT DISTANCES APART. WINTER 1915-16.

Distance between laterals	Maximum discharge an acre in 24 hours	Mean discharge an acre in 24 hours	Mean daily rain previous 2 days	Daily outflow	Tile per acre	Mean acre inch discharge per 1000 feet of tile in 24 hours
Ft.	*Acre-In.*	*Acre-In.*	*In.*	%	*Ft.*	
25	1.20	.48	.60	80	1,742	.27
50	1.35	.55	.60	92	872	.63
75	.80	.33	.60	55	586	.56
100	.90	.32	.60	53	436	.73

Tile should handle a half inch of rain a day. Drainage measurements (Table II) show that in heavy weather a good tile system should remove a half inch of rain an acre each twenty-four hours. During unusual storm periods as much as an inch an acre per day has been measured going out from the experimental tile system. From 50 to 80 percent of the rainfall passed through the soil and out through the tile. Seventy-three percent has passed through 4-foot columns of this soil in experimental drainage bins of concrete. Except for periods of heavy weather of four or five days' duration, the drainage is not apt to exceed a third of an inch to the acre. It is recommended that tile mains have capacity to handle one-half inch up to 40 acres in area, and one-third inch to the acre for larger areas. The number of acres that tile of different sizes will serve is shown by Table III.

Construction of drainage systems. Early spring is the most suitable time of the year for observing the need of tile drains and for constructing tile systems in Western Oregon.

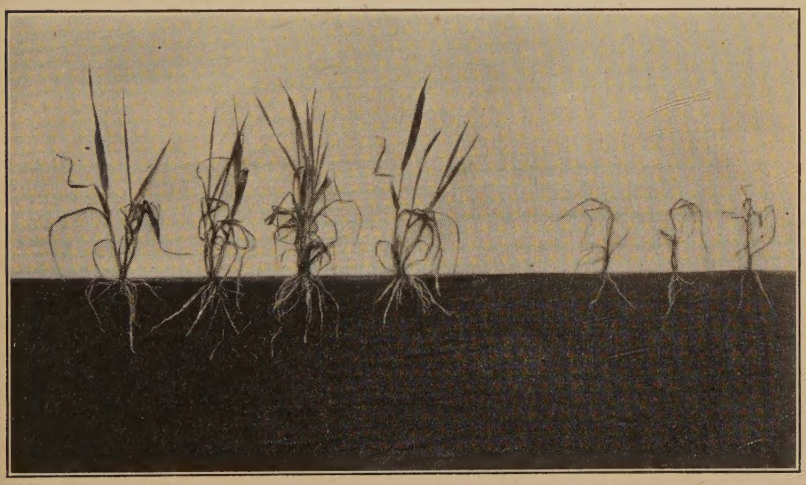

Figure 3. Effect of good vs. poor drainage on roots.

TABLE III. CAPACITY OF MAIN DRAINS (1000 FEET IN LENGTH)

(Acres drained of ½-inch rainfall per 24-hour day by tile of different sizes.)

Tile diameter	Fall for each 100 feet					
	0.05 ft. ⅝ in.	0.10 ft. 1 3/16 in.	0.2 ft. 2⅜ in.	0.3 ft. 3⅝ in.	0.4 ft. 4¾ in.	0.5 ft. 6 in.
	Acres of land drained					
In.						
5	8.8	9.9	11.7	13.3	15.0	16.0
6	14.0	15.6	18.5	21.0	23.2	25.2
8	28.6	32.0	37.8	42.9	47.5	51.6
10	50.0	55.6	65.8	74.6	82.6	89.6
12	76.1	87.4	103.4	117.2	129.6	140.9

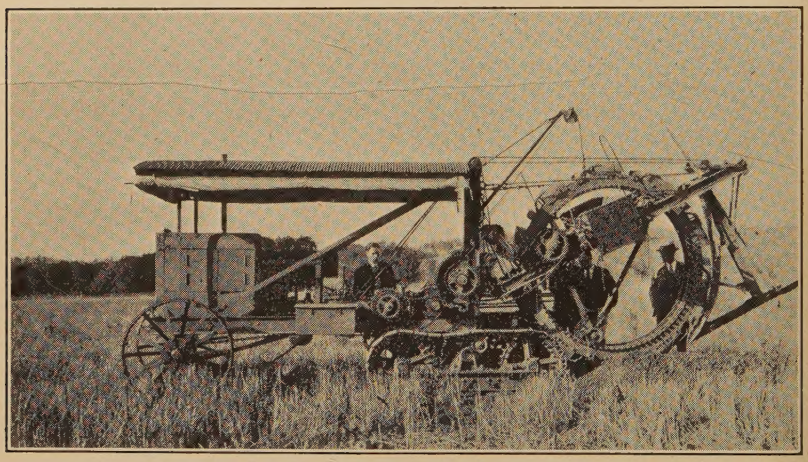

Figure 4. "Little Wonder Ditcher."

A preliminary drainage survey with the aid of a soil auger and surveyor's level should be made to yield information as to the extent of the wet area, the route for the outlet drain, and the subsoil and ground-water conditions. This will be followed by a detailed survey providing grade stakes every 100 feet along each proposed tile line on which levels are taken. Wherever there is less than 6 inches fall per 100 feet it is advisable to lay the tile to a surveyed grade. This will add perhaps 5 percent to the cost and may add 50 percent to the efficiency of the system.

Design of under-drain systems. An under-drainage system should be planned to include all the wet areas of the whole farm, although such a system can be installed in units as convenient, the most necessary lines first. Where the land is to be plowed before tiling, it is useless to set grade stakes.

Rules to observe in locating drains are:

(1) Lay the main drain in the line of natural drainage. Run the laterals in the direction of greatest slope.
(2) Use long parallel laterals to avoid double drainage.
(3) Use straight lines or gradual curves.
(4) Plan a complete system to serve the entire wet area.
(5) Use a surveyor's level wherever there is little fall.
(6) Bring all the wet land under influence of the drains.

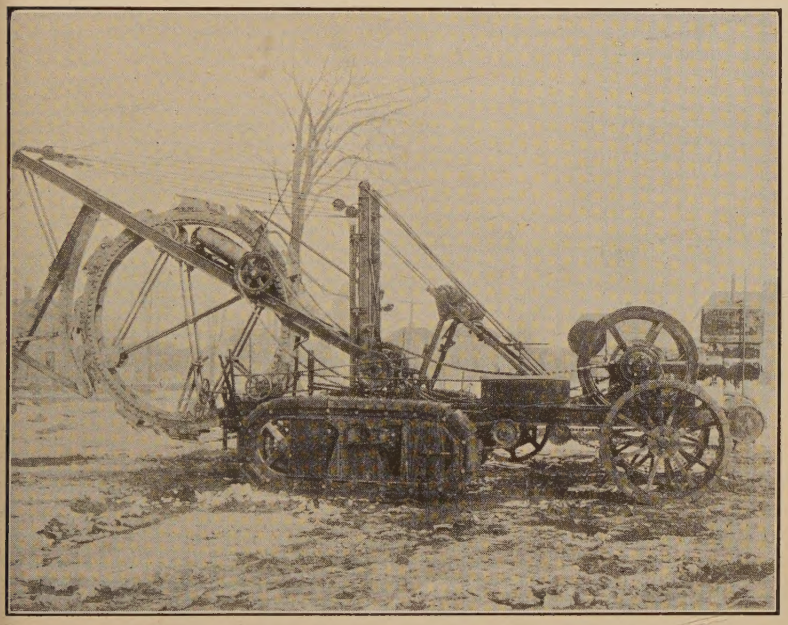

Figure 5. Buckeye Trencher.

Next to the outlet drain the intercepting or foot-hill drain is the most important part of a drainage system. This should be located to traverse along the base of the slope and should have a fall of perhaps 6 inches per 100 feet.

Getting the tile. The survey will show the number of tiles needed, which should be listed to indicate the lines along which different sizes are to be delivered, and will show the total number of feet needed. Tiles are best ordered in car lots delivered to the nearest railroad station. They can be hauled directly from the car to the trenches and placed within reach of the tiler standing in the trench. Farm drains have been largely built of well-burned clay tile. Carefully made concrete tiles are now perfected so that they can be used where the soil is not highly acid or alkaline. Under highly acid or alkaline conditions their use is not past the experimental stage.

Trenching machinery. Where many long parallel lines of tile are to be installed and the land is reasonably free from obstacles, a trenching machine may be employed. A heavy type of trenching machine used for farm drainage has a rotary cutting wheel driven by a gasoline engine and mounted on caterpillar wheels. It is operated so as to cut to an established grade by means of targets.

The "Little Wonder Ditcher" has been used locally with good success. It operates somewhat on the principle of a plow, taking off several inches of earth at each trip until a ditch 30 to 36 inches deep has been made. This ditch can then be finished to grade by hand. The "Martin Ditcher" or steel "V" opens a surface run or removes the surface spading economically when soil is in condition for plowing. Lack of skilled labor for tiling has increased the demand for trenching machinery.

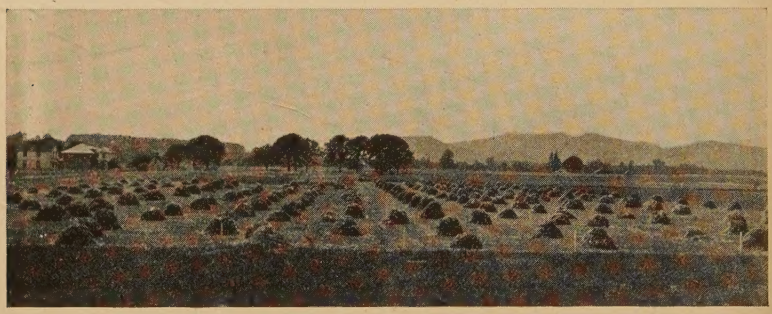

Figure 6. Clover on drainage experiment field.

Where a fair fall is obtainable and running water can be obtained, it is possible in friable soils to sluice out a ditch. A scarifying tool, similar to a thresher cylinder, has been developed by Mr. Purvis of Vale in connection with alkali land reclamation experiments there and has been used in constructing some fairly deep drains in Malheur county at a cost of about half as much as by former methods. With this method there is no unsightly waste bank. A lateral is graded and several feet of water run through while this ditcher is drawn back and forth in the trench to file out the ditch to the desired depth.

Blasting ditches for drains has been practiced by F. E. Price, Agricultural Engineer. This method is especially useful for straightening the channels of smaller streams or constructing outlet ditches under marshy or brushy conditions. Charges are placed in a straight line from 1½ to 2. feet apart. This method scatters the spoil earth over a large area. The method is adapted to providing ditches from 3 to 4 feet wide up to 8 or 10 feet in width and from 3 to perhaps 6 feet deep. The method is not practical for a smaller ditch. The cost for explosives for the smaller ditch will be about 6¢ per linear foot of ditch and for the larger ditch 10 to 15¢ per linear foot, depending upon the soil conditions.

Hand work. The use of a plow in starting a trench is favored only in tough sod or where work is done with unskilled hand labor. A trench 3 feet deep can be provided by removing two courses, spading it with a tile

spade. Such a trench should be started at about 11 or 12 inches wide at the top. A three-course ditch will need to be 16 inches wide at the top. In starting the ditch, a guide string is strung on the ground at one side of the ditch. At bends a ¼-inch rope should be laid on the ground in a smooth curve. The trench should be kept straight and the sides smooth and plumb. A skilled spademan will not leave much loose earth in the bottom of the trench. If the weather is dry, the soil crumbs should be left in the trench until the second spading is to be dug. A round-pointed shovel is used to remove this.

Grade lathes are set over the surveyor's stakes to carry a grade line parallel to and a definite number of feet above the proposed ditch bottom (Figure 7). The depth to dig at each station is calculated from the elevation of the hub stakes. The last inch or two is removed with a tile scoop, leaving a smooth, firm U-shaped tile base which is dressed to grade ready to receive the tile. The gauge stick should be used to test the depth of the ditch from the grade wire every foot or so. When several feet of trench is prepared, the placing of the tile can begin.

Laying the tile. Laying should start at the outlet and proceed up stream on a firm tile base. The tile should be placed in a straight line with the long side up so that the joints fit tightly at the top side and are nearly flush at the lower inside edge. Openings larger than ⅛ inch should be covered with pieces of broken tile. The tile may be rotated to fit together on top and imperfections in tiles may be taken advantage of in making slight turns. Where a soft condition is encountered in the tile trench, it is best to lay the tile on a board or on a V-shaped trough. Burlap or straw may be used to prevent quicksand entering the joints. Curves may be fitted by carefully shaping off the inside edge of the tile with a chisel and hammer. Y's can be constructed, but it is best to order these on the tile bill. Inspection of the tile lines should be made before filling. A level can be used to test the line at frequent intervals for dips or swells in the grade.

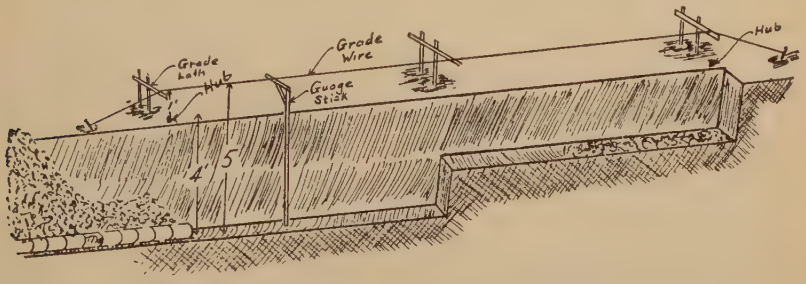

Figure 7. Method of laying tile to grade.

Blinding in. Tiles are blinded by a workman who stands beside the trench and shaves mellow earth from the sides of the ditch with a spade. A layer of mellow earth 2 or 3 inches deep prevents the tile from getting out of place. Plowing off the shoulders of the trench will put the mellow surface soil near the tile to facilitate entrance of water. A light road grader or "V" crowder can be used to finish the back filling. Filling is more readily accomplished before the earth has become compact and settled.

Cost of tiling. Cost for moderate-sized mains and laterals may run 40¢ to 60¢ a rod for digging, laying, and blinding, with backfilling 10¢ to 15¢ per hundred feet additional. Four-inch clay tiles are now $3.75 per 100, and if trenching were 50¢ a rod, or $3.00 per hundred feet, the total cost of lateral tile would run about $1.12 per rod installed.

Outlet. A permanent tile outlet with free discharge is of primary importance. Use a collecting or main drain to bring all the water together and discharge it into the open stream at one point with volume and velocity sufficient to be self-cleaning. A submerged outlet is objectionable because land will never drain below the level of water in the outlet. Near the outlet a vitrified pipe or one laid in cement, or a corrugated culvert which is not affected by freezing or tramping by animals, should be used.

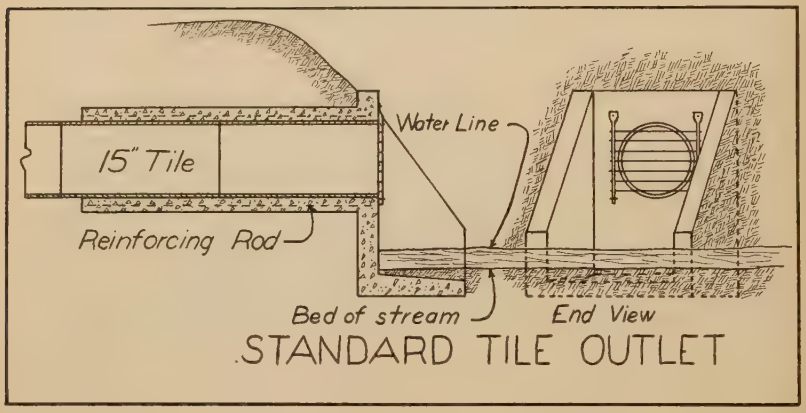

Figure 8.

The end of the outlet should be screened with quarter-inch iron rods placed 1¼ inches apart and arranged horizontally to prevent rodents from entering the tile. This screening can be hinged from the top to permit cleaning out. Providing a retaining wall will force the water to run out through the last tile instead of cutting out around it. This will also retain the earth bank and serve as a monument. The footing should extend out into the stream bed, forming an apron to prevent erosion (Figure 8).

Surface inlets and silt basins. These structures are usually located in fence corners where two or more lines of tile join or where there is a change to a lesser grade. They afford a means of inspection and of collecting and cleaning out silt, help collect surface flood water quickly, prevent the drain from becoming clogged, and may sometimes be arranged to afford watering places for stock. A small inlet can be constructed by placing a large sewer tile on end and covering with screening at the top or surface of the field. The silt basin should extend perhaps 2 feet below the tile drain to provide a settling basin to any further silt. A settling basin may be 4 or 5 feet broad and 4 feet deep and water may be siphoned from it to the outlet basin, which it enters on a grade to avoid roiling up the silt (Figure 9).

Does drainage pay? Drainage in experimental fields studied has doubled the yield. Before drainage the crop yield was so low that profit was uncertain. The larger crop has insured a good profit. Following drainage in 1915 when winter barley drowned out in part on untiled land that yielded 12 to 15 bushels an acre, the yield of tiled land at different spaces ran as high as 33.73 bushels for the closest spacing as follows:

Distance between laterals (feet)	*Yield of barley per acre in 1915 (bushels)*
Ft.	*Bu.*
25	33.73
50	29.90
75	27.90
100	20.35
Undrained	15.00

A piece of white land in the irrigation field south of the railroad on the College farm was tiled in 1921. This area had previously been abandoned to pasture. The first crop following drainage was white beans. The yield without fertilizer was 11 bushels of beans, which sold for $3 a bushel. The tile lines are 5 rods apart. The material or tile cost at this spacing was $20 an acre. The tiling was installed by students as class work but would have cost $20 an acre to install. Seven bushels of beans returned the money paid out for tile.

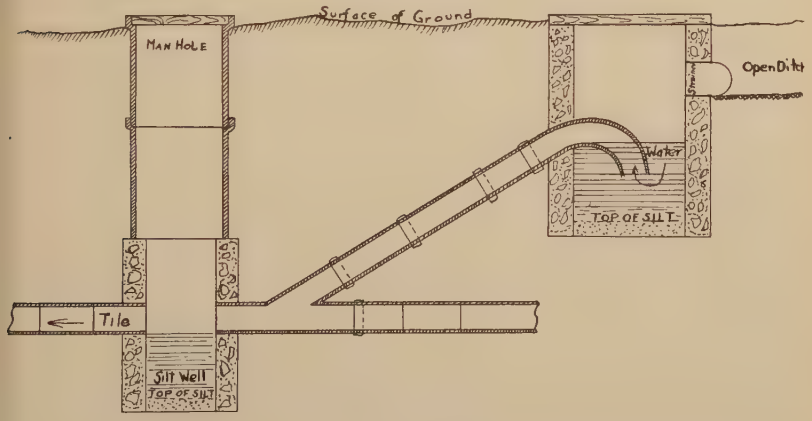

Figure 9. Inlet.

Those who have tried it say that it pays to tile white land. Timely drainage pays in increased yields and increased land values. It is the most permanent improvement that can be put upon land. Every acre of our white land can be tiled, and it will pay a better rate of interest on the total investment when drained than it pays undrained.

Improvement of white lands. The drainage experiment field (Figure 1) was divided into approximately half-acre plots, and treated with different applications following drainage to build up the soil. Analysis of the white land shows that it contained the following amounts of plant food in the top $6\frac{2}{3}$ inches of soil at the time it was drained.

TABLE IV. CHEMICAL ANALYSIS OF WHITE LAND

Plant food element	Total pounds in 2,000,000 (6⅔ in.)	Replaceable bases percent of soil
	Lbs.	*%*
Nitrogen	2,000	.....
Phosphorus	1,311	.....
Calcium	28,200	.1057
Magnesium	4,400	.0122
Potassium	36,178	.0095
Sulfur	560	.....
Sodium	.....	.0501

These lands are distinctly acid. They contain an almost inexhaustible supply of potash, provided it is liberated in amount needed by plants. The supply of phosphorus and sulfur is below average. The supply of nitrogen is scarcely average as the ground is too wet in winter and too dry in summer, and unfavorable for legumes before drainage.

Manure and lime made .7 ton more clover. The first stand of clover was obtained in 1920 on the drained white-land field. Table V gives yields and treatments.

TABLE V. DRAINAGE EXPERIMENT FIELD
Yields (½-acre plots), tons per acre.

	Clover 1921	Corn ensilage 1923	Barley 1924	Oats-and-vetch hay 1925	Corn ensilage 1926	Barley 1927
	Tons	*Tons*	*Bu.*	*Tons*	*Tons*	*Bu.*
Average 3 to 5 checks	2.017	5.743	55.21	1.51	3.86	30.00
Lime 1½ tons	2.447	5.025	66.72	2.89	3.97	35.18
Manure 10 tons	2.715	6.162	64.05	2.99	4.58	39.48
Green manure	2.042	5.675	63.84	2.44	1.78	32.81
Lime and manure	2.731	7.300	58.48	2.03	5.10	35.21
Gypsum and green manure	2.000	9.663	56.61	2.85	3.18	32.62
Lime, manure and green manure	2.900	10.780	63.94	2.06	2.74	31.87
Lime, manure and treble phosphate	.....	6.262	58.01	2.85	4.22	33.27
Lime and manure	.....	4.762	66.56	2.50	4.93	33.68
Gypsum 100 lbs.	.....	.....	54.39	1.75	3.53	30.79
Sulfur 100 lbs.	.....	.....	65.23	1.59	3.49	30.06

In this experiment lime made nearly half a ton increase, while lime and manure made an increase of .7 ton. In 1922, the second crop year of clover, yields were slightly less on account of the dry season, and the quality was reduced on account of more foul growth. The hay in 1921 was of excellent quality.

Manure and lime aid drainage. The drainage of white land is difficult because of the impervious soil structure. Use of both lime and manure following drainage has helped improve the tilth, has increased capacity for usable water, and has aided removal of the excess of water by drainage.

Operations that aid drainage. A number of things can be done to aid tile in collecting water in retentive soil. Seepage water should be intercepted before it reaches retentive, saucer-like areas. Surface inlets at the upper side of the field may prevent water going on to the heavier soil. Leaving the trench open a few weeks will permit the heavy subsoil to slake

TABLE VI. INCHES MONTHLY RAINFALL AND PERCOLATION
White land (Dayton silty clay loam)
Drainage bins 3⅓ x 3⅓ x 4 feet deep. Oregon Agricultural Experiment Station.

Month 1922-23	Rainfall	Percolation			
		Untreated	Limed	Manured	Limed and manured
	In.	*In.*	*In.*	*In.*	*In.*
October	4.88	.75	.98	1.16	.93
November	3.07	3.12	3.37	3.19	3.38
December	11.11	10.93	11.02	12.04	11.44
January	10.88	8.53	9.05	10.20	8.92
February	2.16	1.65	1.41	1.78	1.60
March	2.57	1.68	1.61	1.41	1.43
April	2.71	.63	.85	.78	.72
Total	37.38	27.29	28.29	30.62	28.42
Percent outflow		73.00	76.00	82.00	76.00

and crumble. Putting in sods over the tile will aid the entrance of water. Tiled land should be deeply plowed. Liming will be more effective in mellowing soil after drainage and should make it possible to grow clover, the roots of which will penetrate the drained soil and open up water passages.

Outlets, channels, silt basins, and inlets should be inspected and cleaned if necessary before the rainy season and after heavy storms.

Good farming of drained land is necessary if full returns are to be realized from tile drainage.

Improvement in drainage through heavy soils. Improvement in the drainage properties of heavy soils is largely a matter of bringing about flocculation of the colloidal (jelly-like) clay. Studies have been made with the colloidal clay separated from white land subsoil and from the soil of the alkali experiment field near Vale and also gelatinous muck from the

Figure 10. Wet "white land," Corvallis, February 22, 1927.

Lower Klamath Marsh. Three-gallon jars were treated with different flocculents by Mr. V. D. Young, graduate student in Soils, and their effects on the rate of percolation measured. All treatments employed were found helpful but some excelled others. Increased percolation in order of decrease in magnitude came from treatments with lime and manure, sulfur and manure, green manure, alum, or a saturated solution of calcium sulfate.

Figure 11. Winter barley on tiled "white land." Experiment Field, Corvallis, February 22, 1927.

Clay particles in suspension treated with different chemicals showed a rate of flocculation corresponding closely to the increase with valency and atomic weight. Lime-water caused flocculation almost as rapidly as alum. Application of sulfur or sulfuric acid to the fine clay from the Vale soil neutralizes the alkalinity and increases the active calcium, resulting in flocculation. Even under conditions of high acidity the soil colloids, including the colloids from Klamath peat marsh, migrated under an electric current as though bearing a slight negative electric charge. Flocculation is largely a matter of decreasing this charge. On the acid soil of Western Oregon manure and lime applications, singly or in combination, have increased the flow of drainage in drainage bins and in field plots. In the alkali field sulfur and manure or gypsum and manure have improved the structure and increased the rate of percolation very much.

Plant food in drainage water. Chemical determinations have been made periodically from composite samples of the water from the drainage bins at the Experiment Station. These studies as summarized by Mr. W. M. Higby, formerly of the Soils department, show that applications of lime and manure alone and in combination have increased the loss of total leachings and of the plant nutrients calcium, magnesium, potassium, nitrate, and sulfate. Under moderate weather conditions the first percolate in the fall approximates a displaced soil solution in chemical composition. Calcium is lost in largest amounts of any one nutrient, the average loss being 65 to 70 pounds per acre each year. Nitrates are lost at the rate of 25

to 30 pounds per acre each year. Lime and manure treatments nearly doubled the amounts lost by leaching. Sulfate is lost at the rate of about 50 pounds per acre. The loss is larger from tanks treated with lime the previous season. Magnesium and potassium are lost at rates of 23 and 16 pounds respectively per acre each year. Lime and manure treatments have increased these losses. Phosphate is lost in small amounts from check tanks. Lime and manure treatments decreased the loss of this element. The total drainage in inches is shown in Table VII.

TABLE VII. DRAINAGE AND IMPROVEMENT OF WET LAND: TOTAL LEACHINGS (INCHES)

Treatment	Drainage Bins							
	Willamette Soil				Dayton Soil			
	1 None	2 M,Ca	3 M	4 Ca	5 Ca	6 M	7 M,Ca	8 None
1922-23	12.67	24.06	28.63	27.64	-------	-------	-------	-------
1923-24	6.90	12.61	17.10	14.54	12.03	16.50	16.36	13.34
1924-25	20.55	39.18	37.87	37.05	34.02	36.08	35.40	33.62
1925-26	12.85	17.42	17.56	16.21	16.00	15.70	17.12	16.20
1926-27	31.47	38.96	38.66	37.36	35.97	36.16	36.15	36.06
1927-28	23.32	37.18	35.87	35.73	32.20	34.80	33.04	31.34
1928-29	12.31	23.02	29.63	26.46	25.13	27.83	27.01	24.31

Fertilizer experiment. The white land south of the railroad in the corner of the irrigation field is utilized for fertilizer experiments. The field was in corn in 1920. In 1921 winter grain drowned out. Tiling was then extended through the center of the plot. In 1922 the field was in white beans. The next year (1923) it was in winter barley, which was not drowned out, and was the first successful winter grain crop on this land. The yield from different treatments is given in Table VIII.

Phosphorus and manure did best. The maximum yields were obtained where manure at the rate of 10 tons and superphosphate at 250 pounds an

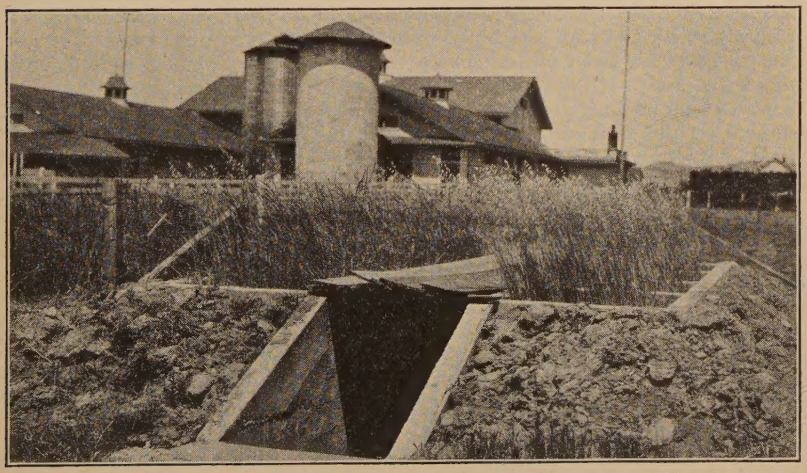

Figure 12. Lysimeters as Drainage bins, Oregon Agricultural Experiment Station.

acre were applied. A gain of nearly 3 bushels of beans worth $9.00 an acre was realized. Lime or fertilizers will be more effective following drainage. Soil in plots represented toward the bottom of the table is somewhat above the average of the range in natural fertility.

TABLE VIII. FERTILITY EXPERIMENT ON "WHITE LAND" 1/10-ACRE PLOTS, IRRIGATION EXPERIMENT FIELD

Plot treatment per acre	Corn ensilage 1920	White beans 1922	Barley 1923	Alsike clover 1924	Corn ensilage 1925	Clover green feed 1927	Corn ensilage 1928	Barley 1929
	Tons	*Bu.*	*Bu.*	*Tons*	*Tons*	*Tons*	*Tons*	*Bu.*
Average 4, untreated	4.22	11.0	46.6	1.76	5.33	2.28	5.77	54.88
Superphosphate 250 pounds	4.73	11.2	33.0	2.29	5.67	2.75	6.05	43.74
Gypsum 100 pounds	4.63	11.0	32.7	2.10	5.25	2.85	4.75	46.66
Nitrate 150 pounds	4.02	11.2	40.4	1.86	4.95	1.92	5.20	49.47
Manure 10 tons	5.33	12.3	60.2	1.73	5.91	2.50	6.65	61.45
Manure 10 tons and superphosphate 250 pounds	4.43	13.8	76.2	1.96	6.77	4.47	8.05	74.37
Manure 10 tons and rock phosphate 500 pounds	4.05	12.2	71.2	1.67	5.72	2.60	7.20	76.04

Crops for drained white land. Vetch is a suitable first crop and may be followed with winter grain, seeding down to clover, with lime disked in after plowing. One and one-half tons an acre is not too much for an initial application of lime. One ton each rotation thereafter may be sufficient. Grain, clover, and some row crop, leaving the clover down one or two years, according to the stand, should, with a little manuring, maintain the organic matter and nitrogen content of this land. To keep up the mineral plant food, sulfur or gypsum may be applied to the young clover, and superphosphate to the cultivated crop. Two hundred and fifty pounds an acre without manure is a suitable application of superphosphate.

Feasibility surveys. A general feasibility survey has been made in cooperation with the United States Office of Drainage Investigations to tie together former surveys of various white-land prairies, and develop a comprehensive plan for the main outlet ditches needed for the Valley. A general map has been prepared and the yardage for the different ditches calculated, and it is found that there are about 250,000 acres in large areas that will require outlet ditches. The average cost of these, including such projects as the Amazon, the Muddy, Dayton Prairie, French Prairie, and Ankeny Bottom will not exceed $10 an acre.

Community ditches. The outlet ditches on small community projects may frequently be started with the large road grader or Steel-V, and in some cases where running water is at hand they may be, in part, sluiced out. They can then be dressed and finished with teams and scrapers and by hand.

Drainage districts. Drainage district law provides a modern, practical means of cooperation for the purpose of securing district outlet ditches. We have 54 successful drainage districts in the state. The assessments are in proportion to benefits, so that every man gets a square deal, and pays in proportion to the drainage he gets. The cost of drainage may be distributed over a period of years, during which time the increased crops provide the money for drainage tax.

The farmer should study subsoil and ground-water conditions in wet areas, then view out a full system of drains by the aid of a level, if necessary. The system may be installed in units, most necessary parts first, but it is best to order tile in car lots. The farmer should make a study of drainage so that he can superintend and inspect his own work. He should sketch the tile lines installed and note results, extending the system as needed.

The community needing an outlet ditch should secure preliminary topographic and soil surveys to learn the costs, feasibility, and extent of the proposed outlet system. If feasible a petition for a drainage district should be prepared according to the state law and presented to the county court. The district officers are then elected and they secure plans and estimates. The county court appoints viewers or assessors, the district officers secure bids, let the contract, and superintend the construction.